

# **Turbulence Fluxes**

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## **LONG-TERM GOALS**

The long-term goal of this program is to understand the processes by which heat and mass are transported vertically by turbulent processes in the ocean in order to estimate the rates of these transports. Our ongoing studies of both the kinematics and dynamics of turbulence and other small-scale physical phenomena in the ocean emphasize observations, a continual program of sensor and instrumentation development, and interaction with turbulence modelers.

## **OBJECTIVES**

Our objectives include determination of:

- the locations of mixing *hot spots* off the west coast of the United States
- salinity gradient spectra - to make the first comprehensive estimates of salinity variance and to investigate the relationship between the turbulent diffusion coefficients for temperature and salinity
- the extent of the departure of wave-zone turbulence from wall-layer scaling
- the Reynolds number dependence of various properties of the energy-containing scales of stratified turbulence.

## **APPROACH**

We are developing an autonomous vertical turbulence profiler, using the *SOLO* buoyancy engine (developed by SIO) for propulsion. It will be used with our deep horizontal profiler (*MARLIN*) in an experiment off the west coast of the U.S. in summer 1999 to find mixing *hot spots*.

Investigation of salinity gradient spectra requires simultaneous resolution of temperature and conductivity gradient spectra. To this end we have developed a thermocouple for making measurements of temperature variance dissipation rate at fast profiler speeds ( $> 1 \text{ m s}^{-1}$ ) and teamed this with a fast, small scale 4-electrode conductivity sensor on our vertical profiler, *CHAMELEON*.

We are completing analysis of data obtained in the Lake Ontario WAVES experiment in which over 500 turbulence profiles through the surface wave zone were made. These well-resolved profiles of turbulent dissipation will be compared to simultaneous spatial series made from a moving vessel, once we have these data in hand.

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We are extending our analyses of energy-containing eddies, fluxes and mixing efficiencies from the ONR-funded FLX91 experiment to other experiments, to assess the influence of buoyancy Reynolds number on the results.

Key individuals are Professors Jim Moum and Douglas Caldwell and graduate student Jonathan Nash.

## **WORK COMPLETED**

Two *SOLO* buoyancy engines have been received from SIO. A transceiving antenna capable of OrbComm satellite data transmission/reception has been developed and tested at sea. This will act as the data link for the autonomous profiler (that we are calling *SOLOCHAM*). Software to control the buoyancy engine is in development.

A thermocouple for use on our turbulence platforms has been designed, constructed, tested and deployed at sea. A paper has been accepted for publication in *J. Atmos. Oceanic Technol.*

Several hundred profiles over the continental shelf of Oregon have been obtained with simultaneous thermocouple-smallscale conductivity measurements. These are being investigated to isolate the T-S cross-spectral component of the conductivity gradient spectrum. A paper is in press in *J. Atmos. Oceanic Technol.*

## **RESULTS**

The thermocouple is capable of resolving temperature gradients at least ten times thinner than can be resolved by the commonly-used thermistor (Figure 1), and has proven to be sufficiently stable for oceanic use, although noise remains a problem in regions of small temperature gradients.

*Figure 1 - Temperature gradient spectra derived simultaneously from an FP07 thermistor (circles) and chromel-constantan thermocouple sensor (triangles).*

Estimates of temperature variance dissipation rates,  $\chi_T$ , and salinity variance dissipation rates,  $\chi_S$ , from highly-resolved conductivity measurements agree with independent estimates from a conventional thermistor probe (Figure 2).

***Figure 2 - Salinity variance dissipation rate from integration of the conductivity gradient spectrum compared to a proxy derived from the temperature gradient spectrum.***

During the course of engineering trials to test new sensors, we have been able to explore some new sites for mixing along the Oregon coast. One of these is Stonewall Bank, off Newport, where a density current was observed to form and flow over the bank., resulting in the formation of an internal hydraulic jump downstream of the bank and highly-sheared flow over the bank (Figure 3), and eddy diffusion coefficients 3 orders of magnitude larger than background values. Figure 3 shows the form of the density current over the bank and indicates an internal hydraulic jump to the left of the bank, with associated intense turbulence. This is one of 12 transects of the bank made on April 19/20 1998.

## **IMPACT/APPLICATION**

The newly-discovered intense mixing over Stonewall Bank must be considered in models of flow over the shelf.

The determination of salinity gradient variance permits a more complete examination of the small-scale entropy generation problem (Gregg, 1984) and, for the first time, a comparison of the eddy diffusivities of heat and salt.

## **TRANSITIONS**

The fast conductivity and temperature probes will be incorporated into all of our turbulence platforms on a more routine basis.

## **RELATED PROJECTS**

- 1) Slope turbulence and internal waves are being investigated in an NSF-funded deployment of the towed body, *MARLIN*. This will be used in conjunction with *SOLOCHAM* in summer 1999.
- 2) A three-component pitot tube is under development with NSF support. This will be used to resolve 3 turbulent velocity components and to complement our new measurements of properties of stratified turbulence from a single platform.

*Figure 3 - Image plots of density (upper panel),  
turbulent dissipation rate (middle panel) and turbulent  
kinetic energy (lower panel), from a single transect  
across Stonewall Bank in April 1998.*

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